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ABSTRACT

The relationships between use of specific tutorial skills and pupil outcomes is the domain of the present paper, the third of three studies of mathematics tutoring designed and conducted using three populations of tutors--teachers, paraprofessionals, and students. The other two studies individually address the effects of tutoring on the achievement and attitudes of fourth and/or fifth grade pupils, and the effects of training in tutorial skills on the achievement and attitudes of fourth and/or fifth grade pupils. Minicourse 5, Individualizing Instruction in Mathematics, is used as the training vehicle for each of the three studies, although the materials are adapted for use with the student tutors. Regression analysis procedures are proposed in order to investigate the relationship of the tutoring skills and interpersonal behaviors to pupil outcomes. The data which forms the basis of the regression analyses consists of frequency counts indicating the number of times that a particular skill is used in the tutorial setting. A more appropriate question in these analyses might have concerned itself not with the quantity of skill usage, but with the quality or appropriateness of a particular skill being used. (Author/AM)

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THE NEED TO STUDY MULTIPLE SKILLS

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THE NEED TO STUDY MULTIPLE SKILLS

Barbara Ivory Williams

Three studies of Mathematics Tutoring were designed and conducted at Far West Laboratory for Educational Research and Development using three populations of tutors -- teachers, paraprofessionals, and students. Each study was designed to address three general areas: (1) the effect of tutoring on the achievement and attitudes of fourth and/or fifth grade pupils; (2) the effect of training in tutorial skills on the achievement and attitudes of fourth and/or fifth grade pupils; and (3) the relationships between use of specific tutorial skills and pupil outcomes. It is this third area which is the domain of the present paper.

Tutor Skills

Minicourse 5: Individualizing Instruction in Mathematics was used as the training vehicle for each of the three studies, although the materials were adpated for use with the student tutors. The tutorial skills which are taught in the Minicourse include:

1. Use of Diagnostic Questions

   These questions were ones which tested the student's understanding of concepts and procedures necessary for the solution of particular problems and were of five types: (1) general diagnostic questions; (2) questions which tested the student's ability to read a problem; (3) questions that tested the students understanding of word definitions; (4) questions that tested the student's understanding

of number concepts; and (5) questions that asked the student to identify number operations appropriate to the solution of a given problem.

2. Use of Prompting questions

These questions encouraged a pupil to perform a particular number operation or discover the solution to a problem.

3. Use of demonstration techniques

Six demonstration techniques were taught in the Minicourse. They included: (1) estimation; (2) diagrams or pictures; (3) number sentences; (4) expanded notation; (5) number lines; and (6) manipulative materials.

4. The use of Verbal Praise

Verbal praise was defined as the oral rewarding of a student who has given the desired or correct response. Although the Minicourse differentiated general praise and specific praise, no distinction was made between the two types of praise due to the results of the main field test of the Minicourse (Gall, 1973) in which specific praise occurred infrequently.

5. Assignment of Evaluation problems

Evaluation problems are those mathematical problems which are given to a tutored pupil to assess the pupil's understanding of number operations and mathematical processes.

6. Assignment of Practice Problems

Practice problems were defined as those mathematics problems which were given to a pupil to provide additional experience in demonstrating understanding of number operations and mathematical processes after the completion of a tutoring session.

Due to the nature of the tutorial setting, a number of other tutorial skills or interpersonal behaviors were identified as potentially important variables. These variables

were:

1. Declarative Statements

   Those statements which provided the pupil with problem-solving information that otherwise could have been obtained from the tutored pupil were considered declarative statements.

2. Constructive Criticism

   The tutors response to student error was considered constructive criticism as long as no element of recrimination could be detected.

3. Recrimination

   Recrimination was defined as occurring when the tutor's criticism gave the clear implication that the pupil should have been doing something else, with a net effect of discouraging the pupil from further ventures.

4. Rapport

   The tone of the tutoring session was defined in terms of the pupil's willingness to be cooperative and the tutor's ability to induce a relaxed, but productive atmosphere.

5. Use of Motivating Statements

   Tutor statements at the conclusion of the tutoring session which were clearly intended to provide encouragement to the tutored pupil were called motivating statements.

In Table 1, each of the above variables is listed along with the nature of the data which defined the variable.

The data for these variables were collected live in the tutoring sessions by observers who were trained in an adaptation of the Flanders Interaction Analysis Coding System (Flanders, 1970). Coding occurred at three second intervals,

TABLE 1

Tutor Variables Studies in the

Mathematics Tutoring Studies

VARIABLE	NATURE OF THE DATA
Diagnostic Questions	mean number of diagnostic questions observed for one tutor across all observed tutoring sessions -- summed over tutored pupils
Prompting Questions	mean number of prompting questions for one tutor across all observed tutoring sessions
Use of Demonstration Techniques (frequency)	mean number of demonstration techniques used in the observed tutoring sessions by one tutor
Use of Demonstration Techniques (time)	mean number of seconds spent using expanded notation, the number line, and manipulative materials for one tutor across observed tutoring sessions
Use of Verbal Praise	mean number of instances of praise among the tutored pupils of one tutor
Assignment of Evaluation Problems(s)	the mean of this dichotomous tutor skill represented the variable
Assignment of Practice Problem(s)	the mean of this dichotomous tutor skill represented the variable

TABLE 1 continued

Delcarative Statements	mean number of statements observed for one tutor across observed sessions
Constructive Criticism	mean number of instances of constructive criticism recorded across all observed sessions
Recrimination	mean number of instances of recrimination recorded across all observed sessions
Rapport	rated 1 (no rapport) to 9 (extremely good rapport) and averaged across all pupils of a given tutor
Motivating Statements	mean of the dichotomous tutor skill represented the variable

unless the interaction changed within the time interval, and was recorded on the Mathematics Tutoring Observation Form (see Table 2).

Analyses and Results

Regression analysis procedures were proposed in order to investigate the relationship of the tutoring skills and interpersonal behaviors to pupil outcomes. The specific pupil outcomes were:

1. Mathematics achievement

   Computational skills were measured by the computation section of the Comprehensive Tests of Basic Skills and Understanding of mathematical concepts was measured by the Modern Math Supplement to the Iowa Tests of Basic Skills. In the case of the Cross-Age Tutoring Study, general mathematics ability was assessed using a teacher-like test -- The Far Wast Laboratory Math Test.

2. Self concept

   Academic and mathematics self-concept were examined using the Modified Sears Self-Concept Inventory.

3. Attitude Toward Mathematics

   Attitude toward mathematics was assessed using the Dutton-Likert Attitude toward Mathematics Scale.

4. External Locus of Control

   The Feelings About Math Scales, developed at Far West Laboratory, was used to determine whether tutoring in mathematics affected pupils' perception of the reinforcement which influenced them in the area of mathematics.

TABLE 2

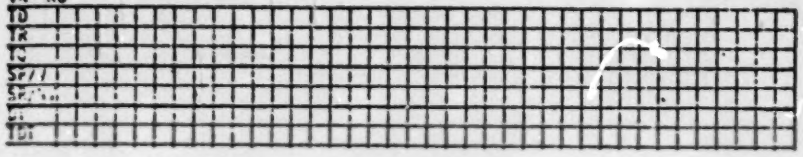
The Mathematics Tutoring Observation Form and Summary Sheet

MTOF Starting Time _____ Ending Time _____

Teacher_____ Student_____

Observer_____ Date_____

VR NO



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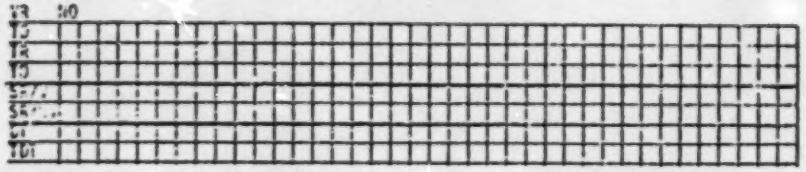

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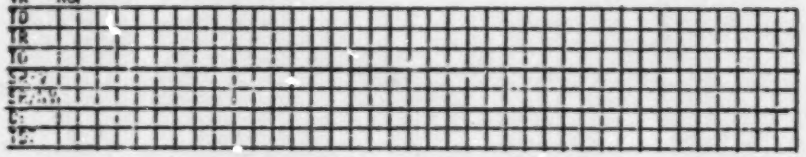

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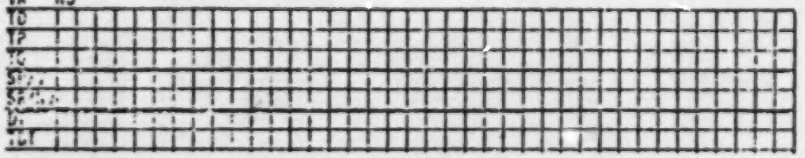

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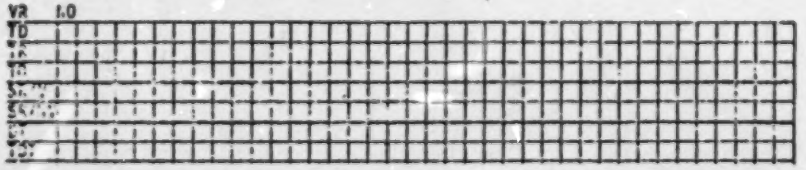

Interruptions_____

Evaluation? YES NO Practice Problems YES NO

Motivating Statement? YES NO Warmth/Rapport 1 2 3 4 5 6 7 8 9

MTOF Summary Sheet

Teacher_____ Date_____

Student_____ Observer_____

Problem_____ NO VR

Evaluation?____ Practice Problems?____ Motivating Statement?____

Warmth/Rapport____ Interruptions_____

QUESTIONS	DEMONSTRATION TECHNIQUES	
Total____	Instances of:	
Type 1_____	Estimation____	
Type 2_____	Diagrams/Pictures____	Total Seconds
Type 3_____	Number Sentences____	_____
Type 4_____	Expanded Notation____	_____
Type 5_____	Manipulatives____	_____
Type 6_____		

COMMENTS:_____

_____

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For the Teacher and Paraprofessional Studies, all dependent and independent variables were arranged into a priori clusters. Cluster A contained pupil pretest scores on all the dependent measures. Cluster B contained the tutoring skills which focused on performance: diagnostic questions, prompting questions, evaluation problems, and practice problems. Cluster C contained the demonstration techniques, both time and frequency and assessed the skillfulness of the tutor in using these techniques. Cluster D was made up of all interpersonal tutor behaviors: praise, rapport, motivating statements, declarative statements, constructive criticism, and recrimination. Cluster E which contained treatment dummy variable and differentiated between those tutors who had received tutorial training and those who had not.

The five clusters of variables were entered into multiple regression equations for each of the six posttest variables at both the fourth and fifth grade levels. Squared multiple correlations (SMC) were computed for various combinations of predictor clusters and then used to compute estimates of the unique contribution to variance of each cluster of variables.

The results of the communality regression analyses for the Teacher Study are presented in Table 3 through 8. Each table presents the fourth and fifth grade results for

one of the six posttest variables. Listed in each table are the squared mutliple correlations for each cluster individually for the five possible combinations of four clusters at a time and for all five clusters combined. Also listed in the tables are the uniqueness estimates for each cluster.

Inspection of the six tables will show that the pupil pretest scores accounted for the greatest amount of variance in posttest scores for each variable with the notable exception of the fifth grade ITBS. After accounting for the unique variance attributable to pupils' initial status, Cluster D which contained the interpersonal behaviors of tutors provided a small unique contribution to variance for most dependent measures, followed by Cluster B which contained the performance tutoring skills. These results were similar to those obtained in the Paraprofessional Study, and therefore, that study will not be reported separately.

The net result of these analyses indicated that tutoring skills and interpresonal behaviors, as contained in Cluster D and B, had a small relationship to mathematics achievement as measured by the CTBS and ITBS. These same clusters also had relatively large uniqueness estimates for the fifth grade attitude toward mathematics measure and external locus of control measure.

A somewhat different analysis approach was used in an attempt to determine the relationships between tutorial skills and pupil outcomes in the Cross-Age Tutoring Study.

TABLE 3

Squared Multiple Correlations and Uniqueness Estimates (Dependent Variable - CTBS)

	Grade 4 (N = 112)		Grade 5 (N - 98)	
Predictor Cluster	Squared Multiple	Uniqueness	Squared Multiple	Uniqueness
A	.423	.218	.283	.218
B	.148	.037	.028	.021
C	.045	.003	.042	.006
D	.177	.054	.094	.028
E	.010	.001	.007	.000
ABCD	.528		.354	
ABCE	.475		.326	
ABDE	.526		.348	
ACDE	.492		.333	
BCDE	.311		.136	
ABCDE	.529		.354	

TABLE 4

Squared Multiple Correlations and Uniqueness Estimates (Dependent Variable - ITBS)

	Grade 4 (N = 112)		Grade 5 (N - 98)	
Predictor Cluster	Squared Multiple	Uniqueness	Squared Multiple	Uniqueness
A	.432	.251	.151	.073
B	.162	.029	.047	.055
C	.009	.007	.035	.032
D	.112	.037	.047	.085
E	.003	.012	.014	.012
ABCD	.490		.247	
ABCE	.465		.174	
ABDE	.495		.227	
ACDE	.473		.204	
BCDE	.251		.186	
ABCDE	.502		.259	

TABLE 5

Squared Multiple Correlations and Uniqueness Estimates (Dependent Variable - Academic Self Concept)

	Grade 4 (N = 112)		Grade 5 (N - 98)	
Predictor Cluster	Squared Multiple	Uniqueness	Squared Multiple	Uniqueness
A	.429	.303	.479	.375
B	.036	.001	.030	.021
C	.039	.005	.003	.007
D	.067	.014	.062	.031
E	.011	.003	.021	.006
ABCD	.454		.523	
ABCE	.443		.498	
ABDE	.452		.522	
ACDE	.456		.508	
BCDE	.154		.154	
ABCDE	.457		.529	

TABLE 6

Squared Multiple Correlations and Uniqueness Estimates (Dependent Variable - Math Self Concept)

	Grade 4 (N = 112)		Grade 5 (N - 98)	
Predictor Cluster	Squared Multiple	Uniqueness	Squared Multiple	Uniqueness
A	.415	.298	.381	.321
B	.086	.004	.014	.017
C	.007	.001	.004	.000
D	.065	.022	.046	.014
E	.011	.006	.007	.001
ABCD	.456		.419	
ABCE	.440		.406	
ABDE	.461		.420	
ACDE	.458		.403	
BCDE	.164		.099	
ABCDE	.462		.420	

TABLE 7

Squared Multiple Correlations and Uniqueness Estimates (Dependent Variable - Attitude Toward Math)

	Grade 4 (N = 112)		Grade 5 (N - 98)	
Predictor Cluster	Squared Multiple	Uniqueness	Squared Multiple	Uniqueness
A	.207	.165	.233	.149
B	.023	.011	.045	.063
C	.061	.013	.004	.012
D	.054	.033	.103	.081
E	.003	.012	.091	.045
ABCD	.283		.379	
ABCE	.262		.343	
ABDE	.282		.412	
ACDE	.284		.361	
BCDE	.130		.275	
ABCDE	.295		.424	

TABLE 8

Squared Multiple Correlations and Uniqueness Estimates (Dependent Variable - External Locus of Control)

	Grade 4 (N = 112)		Grade 5 (N - 98)	
Predictor Cluster	Squared Multiple	Uniqueness	Squared Multiple	Uniqueness
A	.143	.102	.402	.245
B	.039	.047	.106	.102
C	.008	.000	.035	.001
D	.082	.018	.042	.070
E	.055	.029	.038	.009
ABCD	.245		.530	
ABCE	.256		.469	
ABDE	.274		.538	
ACDE	.227		.437	
BCDE	.172		.294	
ABCDE	.274		.539	

Factor analysis was used as a method of reducing the large number of observational variables resulting in nine factors. Factor 1 contained those variables which involved verbal interaction between tutor and tutored pupil. Factors 2 and 6 contained the tutor working and younger working variables, respectively -- both frequency and time. Demonstration techniques were divided among Factors 3, 5, and 7. Factor 4 was a bipolar tutoring style factor which contained recrimination which had a high negative loading and rapport which had a high positive loading. Factor 7 contained the frequency and amount of time that tutors made declarative statements, and the three end of tutoring session skills -- assignment of evaluation problems, assignment of practice problems, and use of motivating statements -- were contained in Factor 8.

Factor scores were computed for each of the nine factors and were entered into regression equations along with the corresponding pre measure for each dependent variable. The regression analyses results are presented in Tables 9 to 15. The format for each of the tables is identical. The variables (factor names and premeasure) are listed in the left column according to the order in which they entered the regression equation. The remaining columns of the summary table list the multiple correlation, the multiple correlation squared, the amount of variance accounted for by the variable (R SQ change), and the simple correlation. In addition, the last two columns contain the raw and adjusted beta weights.

TABLE 9

Regression Analysis: CTBS

Variable	Mult R	R SQ	R SQ Change	Simple R	B	Beta
CTBS pre	0.720	0.519	0.519	0.720	0.794	0.731
F3 Num Line	0.733	0.537	0.018	0.055	1.214	0.128
F6 Tutee Working	0.740	0.547	0.010	0.032	-0.986	-0.102
F2 Tutor Working	0.744	0.554	0.007	0.123	0.766	0.087
F4 Style	0.748	0.559	0.005	0.070	0.693	0.071
F9 Expanded Notation	0.750	0.563	0.004	0.316	0.739	0.068
F5 Manipulatives	0.751	0.565	0.001	-0.081	-0.334	-0.035
F8 End of Session Skills	0.752	0.565	0.001	-0.008	-0.240	-0.022
F1 Verbal Interaction	0.752	0.565	0.000	0.128	-0.124	-0.014
F7 Tutor Talk	0.752	0.565	0.000	0.246	-0.126	-0.014
(Constant)					11.354	

TABLE 10

Regression Analysis: ITBS

Variable	Mult R	R SQ	R SQ Change	Simple R	B	Beta
ITBS pre	0.798	0.637	0.637	0.798	0.899	0.830
F9 Expanded Notation	0.806	0.649	0.012	0.234	-1.298	-0.117
F7 Tutor Talk	0.809	0.655	0.005	0.396	0.554	0.062
F4 Style	0.811	0.658	0.004	0.038	-0.708	-0.071
F8 End of Session Skills	0.814	0.663	0.005	0.042	0.787	0.071
F1 Verbal Interaction	0.185	0.664	0.001	0.231	0.333	0.038
F2 Tutor Working	0.816	0.665	0.001	0.174	-0.297	-0.033
F6 Tutee Working	0.816	0.666	0.000	0.135	0.213	0.021
F5 Manipulatives	0.816	0.666	0.000	-0.048	0.115	0.012
(Constant)					5.614	

TABLE 11

Regression Analysis: FWL

Variable	Mult R	R SQ	R SQ Change	Simple R	B	Beta
CTBS pre	0.586	0.343	0.343	0.586	0.354	0.450
F7 Tutor Talk	0.633	0.400	0.057	0.426	1.654	0.260
F3 Num Line	0.656	0.430	0.030	0.121	1.114	0.162
F9 Expanded Notation	0.667	0.445	0.015	0.315	1.021	0.130
F2 Tutor Working	0.678	0.459	0.014	0.160	0.781	0.122
F4 Style	0.688	0.473	0.014	0.110	0.845	0.119
F5 Manipulatives	0.693	0.480	0.007	-0.101	-0.570	-0.083
F1 Verbal Interaction	0.694	0.481	0.001	0.110	0.177	0.028
F6 Tutee Working	0.694	0.481	0.000	0.090	0.148	0.021
F8 End of Session Skills	0.694	0.482	0.000	0.075	0.111	0.014
(Constant)					6.705	

TABLE 12

Regression Analysis: ATM

Variable	Mult R	R SQ	R SQ Change	Simple R	B	Beta
ATM pre	0.506	0.256	0.256	0.506	0.502	0.500
F4 Style	0.539	0.291	0.035	-0.118	-2.496	-0.199
F8 End of Session Skills	0.554	0.306	0.015	0.122	1.747	0.126
F5 Manipulatives	0.560	0.314	0.008	-0.142	-1.080	-0.090
F6 Tutee Working	0.566	0.321	0.007	0.135	0.914	0.074
F2 Tutor Working	0.571	0.329	0.005	0.134	0.866	0.077
F1 Verbal Interaction	0.573	0.328	0.002	-0.051	-0.524	-0.048
F7 Tutor Talk	0.575	0.330	0.002	-0.024	-0.537	-0.048
F9 Expanded Notation	0.575	0.331	0.0003	0.093	0.258	0.019
F3 Num Line	0.575	0.331	0.0001	0.047	0.127	0.010
(Constant)					31.157	

TABLE 13

Regression Analysis: ACADSC

Variable	Mult R	R SQ	R SQ Change	Simple R	B	Beta
ACADSC pre	0.495	0.245	0.245	0.495	0.547	0.490
F9 Expanded Notation	0.533	0.284	0.039	0.220	4.848	0.193
F8 End of Session Skills	0.559	0.312	0.028	0.181	4.130	0.165
F5 Manipulatives	0.565	0.319	0.007	-0.085	-1.949	-0.089
F7 Tutor Talk	0.572	0.327	0.008	0.087	1.581	0.078
F4 Style	0.576	0.331	0.004	0.017	-1.514	-0.067
F6 Tutee Working	0.579	0.335	0.004	-0.070	-1.534	-0.068
F1 Verbal Interaction	0.581	0.338	0.002	-0.034	-0.959	-0.048
Fs Tutor Working	0.582	0.339	0.001	0.113	0.706	0.035
(Constant)					39.236	

TABLE 14

Regression Analysis: MATHSC

Variable	Mult R	R SQ	R SQ Change	Simple R	B	Beta
MATHSC pre	0.597	0.356	0.356	0.597	0.661	0.603
F7 Tutor Talk	0.641	0.412	0.056	0.231	1.521	0.200
F9 Expanded Notation	0.665	0.443	0.031	0.231	1.698	0.181
F1 Verbal Interaction	0.673	0.453	0.010	-0.010	-0.757	-0.101
F8 End of Session Skills	0.678	0.460	0.007	0.101	0.866	0.093
F5 Manipulatives	0.681	0.464	0.004	-0.145	-0.513	-0.063
F4 Style	0.682	0.465	0.002	0.002	-0.375	-0.044
F6 Tutee Working	0.683	0.466	0.001	0.025	-0.259	-0.031
F3 Num Line	0.683	0.467	0.001	0.033	0.189	0.023
(Constant)					9.404	

TABLE 15

Regression Analysis: EXLOC

Variable	Mult R	R SQ	R SQ Change	Simple R	B	Beta
EXLOC pre	0.507	0.257	0.257	0.507	0.442	0.514
F4 Style	0.556	0.309	0.052	-0.131	-1.308	-0.239
F8 End of Session Skills	0.574	0.329	0.020	0.100	0.751	0.125
F1 Verbal Interaction	0.580	0.336	0.007	-0.068	-0.391	-0.081
F9 Expanded Notation	0.584	0.342	0.005	0.165	0.447	0.074
F7 Tutor Talk	0.588	0.346	0.004	0.266	0.343	0.070
F2 Tutor Working	0.590	0.348	0.002	0.166	0.236	0.048
F5 Manipulatives	0.591	0.349	0.001	0.051	0.176	0.033
F6 Tutee Working	0.591	0.349	0.0001	0.0867	-0.077	-0.014
(Consant)					18.198	

As would be expected, the pupil pretest scores accounted for the greatest amount of variance in the post scores for each of the dependent measures. For the CTBS and ITBS, the combined tutorial skills and interpersonal behaviors accounted for only 5% and 3% of the variance in those post scores. However, for the FWL -- a test a general mathematics ability containing both computational and mathematics concept test items -- 14% of the variance in the post scores was accounted for by the combined tutor skills. The majority of that variance was attributable to the factor containing frequency and time tutors spent using declarative statements.

There was more consistency in the results for the affective measures as the combined tutor skills and interpersonal behaviors accounted for eight to thirteen percent of the variance in those post scores. The end of session skills factor accounted for at least 2% of the variance for each of the affective measures, and the expanded notation factor accounted for 1%, 3% and 4% of the variance in the post measures of external locus of control, mathematics self-concept, and academic self-concept, respectively. Another consistency in the findings was associated with the style factor. For each of the affective measures, plus the FWL, the beta weight for this bipolar factor was negative indicating that the more criticism that occurred in the tutoring sessions, the more positive the attitude, self-concept, and FWL score. The finding is completely counter-intuitive and cannot be explained by the present data.

Discussion

In the Teacher and Paraprofessional Tutoring Studies, a positive relationship between tutoring skills and interpersonal behaviors of tutors to pupil outcomes was not clearly demonstrated, although a cluster of skills which contained the interpersonal behaviors of tutors provided a small unique contribution to variance in pupil post scores. A clearer relationship between tutor skills and pupil outcomes was demonstrated in the Cross-age Tutoring Study, but only when all skills, as represented by the factor scores, were combined.

After exploring and rejecting various possible explanations for the failure of the desired relationships to materialize to any significant degree, including inadequacy of the training and inadequate use of the tutoring skills, the research methodology used in the collection of the observational data was examined.

The data which formed the basis of the regression analyses consisted of frequency counts indicating the number of times that a particular skill was used in the tutorial setting. Even with the a priori clustering of skills in the Teacher and Paraprofessional Studies, and the statistical clustering of skills in the Cross-age Study, the fact remains that the bases for those clusters of skills were frequencies. A more appropriate question in these analyses might have concerned itself, not with the quantity of skill usage, but with the quality or appropriateness of a particular skill

being used. Examination of the results of the community regression analyses in the Teacher and Paraprofessional studies showed that, after the variance attributable to pupil pretest scores was accounted for, the greatest amount of the remaining variance, on each dependent variable, was accounted for by the cluster which contained the tutor interpersonal behaviors. Similar results were obtained in the Cross-Age Study. It is possible that these interpersonal behaviors, which were more dependent upon what particular tutored pupils did in the tutoring session than the skills emphasized in Minicourse 5, demonstrated more positive relationships to pupil outcomes because they were more appropriately used. Although the data collected in the three Math Tutoring Studies cannot provide definitive answers to this question, it is certainly an area which should be addressed in future studies which seek to demonstrate relationships between teaching skills and pupil outcomes.

Although the results of the Math Tutoring Studies raise as many questions as they answer, they are important as a point of departure for other researchers to use in formulating more appropriate methodological models which demonstrate the relationship between teaching and pupil outcomes which we intuitively believe exists.

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